January 23, 2020

Supplemental Discussion on Reverse Lightering

This supplement contains information requested by EPA on January 17th pertaining to reverse lightering.

Background

This document compares project impacts to impacts associated with two scenarios involving the export of a volume of crude oil equivalent to the maximum throughput rate of the proposed SPM project.

Information about reverse lightering has been supplied to EPA in BWTX's submissions dated August 15, 2019, October 23, 2019, and November 15, 2019. Although reverse lightering operations are not a control technology for purposes of the Case-by-case MACT evaluation, BWTX selected its project after considering the environmental impacts of its project as well as impacts associated with other crude oil export methods involving reverse lightering.

Scenarios Considered

A total of three scenarios are considered: the project scenario and two lightering scenarios:

Table 1 Scenarios Considered

Scenario	Description
Project Scenario	Export of 384 MMBbl/yr of crude oil onto VLCC's via SPM buoys.
Lightering Scenario 1	Export of 384 MMBbl/yr of crude oil onto VLCC's via reverse lightering.
Lightering Scenario 2	Export of 384 MMBbl/yr of crude oil onto VLCC's with a partial load onshore, and remaining load via reverse lightering.

The project scenario is the SPM facility described elsewhere in BWTX's application. Lightering Scenario 1 involves the use of Aframax lightering vessels to fill VLCC's via ship-to-ship transfers. Lightering Scenario 2 involves the partial loading of VLCC's at onshore facilities with the remainder of the load completed via ship-to-ship transfers using an Aframax lightering vessel. It is assumed that this scenario would require additional dredging in the vicinity of the Port of Corpus Christi to accommodate VLCC traffic.

For purposes of this analysis, the nominal capacity of an Aframax tanker is 500 MBbl and the nominal capacity of a VLCC is 2,000 MBbl. A partially loaded VLCC receives a partial load of 1,000 MBbl onshore and the remainder of its load via reverse lightering.

The following categories of impacts are assessed. Air emissions are quantified, while impacts to nearshore aquatic environments and impacts to port facility congestion are identified qualitatively.

- Air Emissions: Uncontrolled loading emissions, controlled loading emissions, and vessel engine emissions.

- Impacts to nearshore aquatic environments: Impacts associated with dredging and excavation activities.
- Casualty Risks: Impacts associated with the increased risk of casualty due to congestion and ship-to-ship transfer operations.
- Business Impacts: Anticipated time to complete full loading of a VLCC.

Air Environmental Impacts: Loading and Vessel Engine Emission

Air Emission Rates for the three scenarios are summarized below. Associated emission calculations were originally provided with the 25-Oct submission. The calculations have been revised to include air emissions associated with Lightering Scenario 2, include emissions from lightering support vessels, and to correct an error in the assumed GHG emission factor for vessel engines (Cf. Appendix A).

Table 2 Comparison of Air Emission Rates (tpy)

Pollutant	Project Scenario	Lightering Scenario 1	Lightering Scenario 2
NO_X	1120	6037	4915
CO	307	1452	1183
SO_2	45	214	174
Particulate	39	184	150
VOC	14495	14927	7665
GHG (as CO_2e)	63809	331582	275498
HAP	637	652	333
H_2S	2	2	1

While VOC and HAP emissions are highest for the project scenario and for lightering scenario 1, due primarily to emissions from uncontrolled loading operations, emissions of products of combustion (NO_X, CO, SO_2, Particulate, GHG) are highest for the two lightering scenarios. H_2S emissions are not significant under any of the scenarios. BWTX has conducted dispersion modeling and photochemical modeling for stationary source emissions associated with its projects, finding no adverse impacts.

Non-air Environmental Impacts: Nearshore Aquatic Environments

Of the three scenarios considered, the project scenario and lightering scenario 1 involve relatively minor disruptions to nearshore aquatic environments, while lightering scenario 2 involves more significant impacts. BWTX has considered minimizing impacts to the local aquatic environment as an important priority in selecting its project.

In the vicinity of the Port of Corpus Christi, aquatic environments are particularly sensitive to disruption as larval marine life migrate through the tidal inlet (Aransas Pass) to nursery habitats located throughout the estuary. Disruption of marine larvae can seriously impact fisheries, and lightering scenario 2 is therefore classified as high severity due to required dredging in the tidal inlet. The project scenario involves short-term impacts to these areas (necessary to lay pipelines) which can be managed to prevent such disruptions. Lightering scenario 1 does not involve any disruptions beyond increased vessel traffic.

Table 3 Summary of Impacts to Aquatic Environment

Scenario	Description of Impacts	Severity of Impacts
Project Scenario	Disturbance of seabed for pipeline right of way.	Low
Lightering Scenario 1	None	Low
Lightering Scenario 2	Dredging of nearshore waterways to accommodate VLCC traffic.	High

Casualty Risks

Safety impacts associated with port congestion and lightering operations were discussed in the 15-Nov submission. Increased vessel traffic in port areas increases the risks of groundings, collisions, and spills. Lightering operations also create congestion-related risks because they tend to take place in specific areas offshore of Galveston or Corpus Christi. These operations have an inherently higher risk of casualty than loading at a stationary facility because transfer occurs while both vessels are underway.

BWTX's SPM facility will not increase vessel traffic in the Port of Corpus Christi and will displace loading operations that would otherwise occur via reverse lightering. The project scenario therefore has the lowest casualty risk of the three scenarios.

Table 4 Comparison of Casualty Risks

Scenario	Port Congestion	Ship-to-ship Transfers
Project Scenario	Obviates the need for tanker traffic within the Port of Corpus Christi, potentially reducing congestion.	Complete loading directly onto VLCC at SPM facility in shorter duration. Does not require ship-to-ship transfers.
Lightering Scenario 1	Increased lightering vessel (Aframax-size range) traffic within the Port of Corpus Christi.	Increased ship-to-ship transfers in offshore lightering areas which take longer and have greater commercial impact.

Scenario	Port Congestion	Ship-to-ship Transfers
Lightering Scenario 2	Increased VLCC and lightering vessel (Aframax-size range) traffic within the Port of Corpus Christi and increased support vessels required within port area.	Increased ship-to-ship transfers in offshore lightering areas which take longer and have greater commercial impact.

Business Impacts: Time to Complete Export Operation

An indicator of the overall efficiency of each scenario is the total time required to complete full loading of a VLCC.

Table 5 Summary of Time Requirements for Different Scenarios

Row	Parameter	Value	Comment
1	Time to complete reverse lightering operation	12 hr	Based on analysis of AIS data (15-Aug submission).
2	Time to complete SPM loading operation	25 hr	Based on maximum loading rate of 80 MBbl/hr.
3	Time to complete onshore loading of Aframax	12 hr	Based on loading rate of 40 MBbl/hr.
4	Time to complete partial onshore loading of VLCC	72 hr	Based on analysis of AIS data (15-Nov submission).
5	Transit time to/from offshore lightering area (each leg of voyage)	12 hr	Based on analysis of AIS data (15-Aug submission). The distance from Galveston
6	**Total time for loading 1 VLCC (Project Scenario)**	25 hr	Row 2
7	**Total time for loading 1 VLCC (Lightering Scenario 1)**	192 hr	(2000/500) × (Row 1 + Row 3 + 2×Row 5)
8	**Total time for loading 1 VLCC (Lightering Scenario 2)**	168 hr	(1000/500) × (Row 1 + Row 3 + 2×Row 5) + Row 4

Of the three scenarios, the total time to accomplish a loading operation is the lowest in the project scenario.

The distance that an Aframax lightering vessel covers in traveling between an offshore lightering area and a shoreside terminal facility varies depending on where the lightering operation takes place and where the shoreside terminal is located. For example, the distance from Galveston Offshore Lightering Area (GOLA) to the Port of Texas City is approximately 60 statute miles, while the distance from the Port of Corpus Christi to an associated offshore lightering area is approximately 80 statute miles. As indicated above (Row 5), actual transit times determined from AIS data have been used to estimate Aframax fuel consumption.

Lightering Analysis (Summary)
Bluewater Texas Terminal LLC

Total Emissions by Scenario (tpy)			
Pollutant	Project Scenario	Lightering Scenario 1	Lightering Scenario 2
NO_X	1120	6146	4969
CO	307	1490	1202
SO_2	45	220	177
Particulate	39	189	152
VOC	14495	14932	7667
GHG	63809	339497	279455
HAP	637	652	333
H_2S	2	2	1

Total Emissions by Component Activity (tpy)

Activity	Pollutant	Project Scenario	Lightering Scenario 1	Lightering Scenario 2
Vessel Engines	NO_X	1120	6117	4941
Vessel Engines	CO	307	1469	1181
Vessel Engines	SO_2	45	216	174
Vessel Engines	Particulate	39	187	150
Vessel Engines	VOC	39	188	151
Vessel Engines	GHG	63809	305836	245794
Vessel Engines	HAP	1	3	2
Loading Emissions (uncontrolled)	VOC	14456	14601	7373
Loading Emissions (uncontrolled)	HAP	636	642	324
Loading Emissions (uncontrolled)	H_2S	2	2	1
Loading Emissions (controlled)	VOC	0	143	143
Loading Emissions (controlled)	HAP	0	6	6
Loading Emissions (controlled)	SO_2	0	4	4
Loading Emissions (controlled)	NO_X	0	29	29
Loading Emissions (controlled)	CO	0	21	21
Loading Emissions (controlled)	Particulate	0	2	2
Loading Emissions (controlled)	GHG	0	33660	33660

Supporting Calculations (Vessel Emissions for Lightering Scenario 1)
Bluewater Texas Terminal LLC

Vessel Engine Emission Factors

Pollutant	Emission Factor (lb/hp-hr)
NOx (VLCC and Aframax)	0.0237
NOx (Tug & LSV)	0.0158
CO	0.0055
SO_2	0.0008
$PM/PM_{10}/PM_{2.5}$	0.0007
VOC	0.0007
CO2e	1.1450
HAP	0.000011

Maximum Engine Loads

Vessel Type	Maximum Load (kW)	Maximum Load (hp)
VLCC	26000	34866
Aframax	13000	17433
Tractor Tug		10000
Lightering Support Vessel (LSV)	1119	1500

Operating Levels

Lightered Load (MBbl)	Total Throughput (MBbl/yr)
500	384000

Vessel Activities Per Lightered Load

Vessel Type	Operating Mode	Number of Vessels	Engine Load	Duration (hr)
Aframax	In transit (loaded)	1	90%	12
Aframax	In transit (unloaded)	1	60%	12
Aframax	Lightering	1	90%	12
Aframax	Docked (loading)	1	10%	12
VLCC	Lightering	1	25%	12
Tractor Tug	Mooring assist	2	100%	3
LSV	Lightering Support	1	100%	12

Maximum Emission Rates (lb/event)

Pollutant	Onshore Aframax engines	Onshore assist tugs	Transit	Lightering	LSVs
NO_X	495	789	7428	6933	284
CO	115	275	1726	1611	99
SO_2	17	40	254	237	15
$PM/PM_{10}/PM_{2.5}$	15	35	220	205	13
VOC	15	35	221	206	13
CO2e	23953	57250	359294	335341	20610
HAP	0.2	0.6	3.5	3.2	0.2

Emission Factors (lb/MBbl)

Pollutant	Onshore tanker engines	Onshore assist tugs	Transit	Lightering	LSVs
NO_X	0.99	1.58	14.86	13.87	0.57
CO	0.23	0.55	3.45	3.22	0.20
SO_2	0.03	0.08	0.51	0.47	0.03
$PM/PM_{10}/PM_{2.5}$	0.03	0.07	0.44	0.41	0.03
VOC	0.03	0.07	0.44	0.41	0.03
CO2e	47.91	114.50	718.59	670.68	41.22
HAP	0.0005	0.0011	0.007	0.006	0.0004

Emission Rates (tpy for equivalent volume exported)

Pollutant	Onshore tanker engines	Onshore assist tugs	Transit	Lightering	LSVs	Grand Total
NO_X	190	303	2852	2662	109	6117
CO	44	106	663	619	38	1469
SO_2	6	16	97	91	6	216
$PM/PM_{10}/PM_{2.5}$	6	13	84	79	5	187
VOC	6	14	85	79	5	188
CO2e	9198	21984	137969	128771	7914	305836
HAP	0.1	0.2	1.3	1.2	0.1	3

Notes:

1.VOC, NOx, PM, CO and SO_2 emissions are based on AP 42 section 3.4 emission factors. SO2 emission factor adjusted to account for 1000 ppmw sulfur concentration.
2. NOx emission factors for marine diesel engines based on MARPOL Annex VI emission limit.
3. Operating load and activity duration estimates explained in Sec. 13.
4. HAP emissions are the sum of AP-42 section 3.4 emission factors for Formaldehyde, Acrolein, Acetaldehyde, BTX, and total PAHs.
5. Brake-specific fuel consumption (BSFC) of marine diesel assumed to be 7000 Btu/hp-hr (AP-42 Sec. 3.3).
6. GHG emission factors per 40 CFR Part 98, Subpart C, Tables C-1 and C-2 (Distillate Fuel Oil No. 2).

Supporting Calculations (Vessel Emissions for Lightering Scenario 2)
Bluewater Texas Terminal LLC

Vessel Engine Emission Factors

Pollutant	Emission Factor (lb/hp-hr)
NOx (VLCC and Aframax)	0.0237
NOx (Tug and LSV)	0.0158
CO	0.0055
SO_2	0.0008
$PM/PM_{10}/PM_{2.5}$	0.0007
VOC	0.0007
CO2e	1.1450
HAP	0.000011

Maximum Engine Loads

Vessel Type	Maximum Load (kW)	Maximum Load (hp)
VLCC	26000	34866
Aframax	13000	17433
Tractor Tug		10000
Lightering Support Vessel (LSV)	1119	1500

Operating Levels

Lightered Load (MBbl)	Total Throughput (MBbl/yr)	Partial Load (MBbl)
500	384000	1000

Vessel Activities Per Lightered Load

Vessel Type	Operating Mode	Number of Vessels	Engine Load	Duration (hr)
Aframax	In transit (loaded)	1	90%	12
Aframax	In transit (unloaded)	1	60%	12
Aframax	Lightering	1	90%	12
Aframax	Docked (loading)	1	10%	12
VLCC	Lightering	1	25%	12
VLCC	Docked (loading)	1	10%	48
VLCC	In transit (loaded)	1	90%	12
VLCC	In transit (unloaded)	1	60%	12
Tractor Tug	Mooring assist	2	100%	3
LSV	Lightering Support	1	100%	12

Maximum Emission Rates (Partial load portion, lb/event)

Pollutant	Onshore tanker engines	Onshore assist tugs	Transit	Lightering	LSVs
NO_x	3962	789	14857	0	0
CO	920	275	3452	0	0
SO_2	135	40	508	0	0
$PM/PM_{10}/PM_{2.5}$	117	35	439	0	0
VOC	118	35	442	0	0
CO2e	191624	57250	718588	0	0
HAP	2	1	7	0	0

Emission Factors (Partial load portion, lb/MBbl)

Pollutant	Onshore tanker engines	Onshore assist tugs	Transit	Lightering	LSVs
NO_x	3.96	0.79	14.86	0	0
CO	0.92	0.28	3.45	0	0
SO_2	0.14	0.04	0.51	0	0
$PM/PM_{10}/PM_{2.5}$	0.12	0.04	0.44	0	0
VOC	0.12	0.04	0.44	0	0
CO2e	191.62	57.25	718.59	0	0
HAP	0.0018	0.0006	0.0069	0	0

Maximum Emission Rates (Lightering portion, lb/event)

Pollutant	Onshore tanker engines	Onshore assist tugs	Transit	Lightering	LSVs
NO_x	495	789	7428	6933	284
CO	115	275	1726	1611	99
SO_2	17	40	254	237	15
$PM/PM_{10}/PM_{2.5}$	15	35	220	205	13
VOC	15	35	221	206	13
CO2e	23953	57250	359294	335341	20610
HAP	0.2	0.6	3.5	3.2	0.2

Emission Factors (Lightering portion, lb/MBbl)

Pollutant	Onshore tanker engines	Onshore assist tugs	Transit	Lightering	LSVs
NO_x	0.99	1.58	14.86	13.87	0.57
CO	0.23	0.55	3.45	3.22	0.20
SO_2	0.03	0.08	0.51	0.47	0.03
$PM/PM_{10}/PM_{2.5}$	0.03	0.07	0.44	0.41	0.03
VOC	0.03	0.07	0.44	0.41	0.03
CO2e	47.91	114.50	718.59	670.68	41.22
HAP	0.0005	0.0011	0.007	0.006	0.00

Emission Rates (tpy for equivalent volume exported)

Pollutant	Onshore tanker engines	Onshore assist tugs	Transit	Lightering	LSVs	Grand Total
NO_x	475	227	2852	1331	55	4941
CO	110	79	663	309	19	1181
SO_2	16	12	97	45	3	174
$PM/PM_{10}/PM_{2.5}$	14	10	84	39	2	150
VOC	14	10	85	40	2	151
CO2e	22995	16488	137969	64386	3957	245794
HAP	0.2	0.2	1	1	0.04	2.4

Notes:

1.VOC, NOx, PM, CO and SO_2 emissions are based on AP 42 section 3.4 emission factors. SO2 emission factor adjusted to account for 1000 ppmw sulfur concentration.
2. NOx emission factors for marine diesel engines based on MARPOL Annex VI emission limit.
3. Operating load and activity duration estimates explained in Sec. 13.
4. HAP emissions are the sum of AP-42 section 3.4 emission factors for Formaldehyde, Acrolein, Acetaldehyde, BTX, and total PAHs.
5. Brake-specific fuel consumption (BSFC) of marine diesel assumed to be 7000 Btu/hp-hr (AP-42 Sec. 3.3).
6. GHG emission factors per 40 CFR Part 98, Subpart C, Tables C-1 and C-2 (Distillate Fuel Oil No. 2).

Supporting Calculations (Vessel Emissions for Project Scenario)
Bluewater Texas Terminal LLC

Equipment source	Number of Vessels	Pollutant	Power (hp)	Power (kw)	Speed (rpm)	Load Factor (%)	Annual Operation (hr)	Emissions Factor		Emissions per vessel	
								Value	Units	lb/hr	tpy
Work boat	2	NOx	1,500	1,119	750	25.00%	8,760	0.0158	lb/hp-hr	5.92	25.92
		CO						0.0055	lb/hp-hr	2.06	9.03
		SO_2						0.001	lb/hp-hr	0.30	1.33
		$PM/PM_{10}/PM_{2.5}$						0.0007	lb/hp-hr	0.26	1.15
		VOC						0.0007	lb/hp-hr	0.26	1.16
		CO2e						1.1450	lb/hp-hr	429.38	1880.66
		HAP						0.000011	lb/hp-hr	0.004	0.02
Tug boat	2	NOx	10,000	7,457	750	25.00%	8,760	0.0158	lb/hp-hr	39.45	172.78
		CO						0.0055	lb/hp-hr	13.75	60.23
		SO_2						0.001	lb/hp-hr	2.02	8.86
		$PM/PM_{10}/PM_{2.5}$						0.0007	lb/hp-hr	1.75	7.67
		VOC						0.0007	lb/hp-hr	1.76	7.72
		CO2e						1.1450	lb/hp-hr	2862.50	12537.75
		HAP						0.000011	lb/hp-hr	0.03	0.12
VLCC propulsion engine	2	NOx	34,866.57	26,000	100	10.00%	8,760	0.0237	lb/hp-hr	82.54	361.52
		CO						0.0055	lb/hp-hr	19.18	83.99
		SO_2						0.001	lb/hp-hr	2.82	12.35
		$PM/PM_{10}/PM_{2.5}$						0.0007	lb/hp-hr	2.44	10.69
		VOC						0.0007	lb/hp-hr	2.46	10.77
		CO2e						1.1450	lb/hp-hr	3992.22	17485.94
		HAP						0.000011	lb/hp-hr	0.04	0.17

Pollutant	Total Emissions (tpy)
NO_X (VLCC)	723
NO_X (Tug and Workboat)	397
CO	307
SO_2	45
Particulate	39
VOC	39
GHG	63809
HAP	0.6

Notes:
1.VOC, NOx, PM, CO and SO_2 emissions are based on AP 42 section 3.4 emission factors. SO2 emission factor adjusted to account for 1000 ppmw sulfur concentration.
2. NOx emission factors for marine diesel engines based on MARPOL Annex VI emission limit.
3. GHG emission factors per 40 CFR Part 98, Subpart C, Tables C-1 and C-2 (Distillate Fuel Oil No. 2). Brake-specific fuel consumption of 7000 Btu/hp-hr assumed.

Supporting Calculations (Controlled and Uncontrolled Loading Emissions)
Bluewater Texas Terminal LLC

Constants

Quantity	Units	Value
Vapor Phase MW (hourly)	lb/lbmol	60.3
Vapor Phase MW (annual)	lb/lbmol	59.4
Ambient Temp. (hourly)	°F	95
Ambient Temp. (annual)	°F	72.1
Product:		Crude Oil
VP (hourly)	psia	9.32
VP (annual)	psia	6.44
Annual Throughput	MBbl/yr	384000
Pumping Rate (SPM Loading)	MBbl/hr	80
Pumping Rate (Lightering)	MBbl/hr	40
H_2S Max Vapor Concentration	ppmw	130
HAP Max Vapor Concentration	wt. %	4.4%
Control Device Destruction Efficienty	%	99%
Capture System Efficiency	%	99%
Vapor Heat Content	Btu/lb	20000
Saturation Factor		0.2
Loading Loss Factor (hourly)	lb/MBbl	106.0
Loading Loss Factor (annual)	lb/MBbl	75.3

Emission Factors

Activity	Pollutant	Hourly EF (lb/MBbl)	Annual EF (lb/MBbl)
Uncontrolled Loading	VOC	106.0	75.3
Uncontrolled Loading	HAP	4.7	3.3
Uncontrolled Loading	H_2S	0.014	0.010
Dockside Loading (Uncaptured Emissions)	VOC	1.060	0.753
Dockside Loading (Uncaptured Emissions)	HAP	0.047	0.033
Dockside Loading (Uncaptured Emissions)	H_2S	0.00014	0.00010
Dockside Loading (Controlled)	VOC	1.050	0.745
Dockside Loading (Controlled)	HAP	0.046	0.033
Dockside Loading (Controlled)	SO_2	0.026	0.018

Activity	Pollutant	EF (lb/MMBtu)	Units
Dockside Loading (Controlled)	NO_X	0.1	lb/MMBtu
Dockside Loading (Controlled)	CO	0.074	lb/MMBtu
Dockside Loading (Controlled)	Particulate	0.0075	lb/MMBtu
Dockside Loading (Controlled)	GHG	117.6	lb/MMBtu

Activity	Pollutant	Emission Rate (lb/hr)	Emission Rate (tpy)
SPM Loading (Uncontrolled)	VOC	8483.71	14455.96
SPM Loading (Uncontrolled)	HAP	373.28	636.06
SPM Loading (Uncontrolled)	H_2S	1.10	1.88
Lightering (Uncontrolled)	VOC	4241.86	14455.96
Lightering (Uncontrolled)	HAP	186.64	636.06
Lightering (Uncontrolled)	H_2S	0.55	1.88
Dockside Loading (Uncaptured Emissions)	VOC	42.42	144.56
Dockside Loading (Uncaptured Emissions)	HAP	1.87	6.36
Dockside Loading (Uncaptured Emissions)	H_2S	0.01	0.02
Dockside Loading (Controlled)	VOC	41.99	143.11
Dockside Loading (Controlled)	HAP	1.85	6.30
Dockside Loading (Controlled)	SO_2	1.04	3.54
Dockside Loading (Controlled)	NO_X	8.40	28.62
Dockside Loading (Controlled)	CO	6.22	21.18
Dockside Loading (Controlled)	Particulate	0.63	2.15
Dockside Loading (Controlled)	GHG	9877.1	33660

Notes:
1. NO_X and VOC Emission Factors Explained in Sec. 13
2. H_2S Emission Factor Explained in Appendix Z (PSD Application)
3. SO_2 Emission Factor Based on Complete Combustion of H_2S in Waste Stream
4. Particulate and GHG Emission Factors from AP-42 Sec. 1.4
5. CO Emission Factor Based on 100 ppmv (3% O_2 reference), based on typical TCEQ BACT requirements.
6. VOC emission factor based on hydrocarbon vapor pressure from speciation analysis